Climate Models: Needs for Future Aerosol Measurements

Today	Tomorrow
2° x 2.5° x 30 levels 10s of tracers “massy” aerosols limited mixture set limited chemistry	0.1° x 0.1° x 100s levels coupled system models 1000s of tracers size-resolved aerosols complex composition coupled online chemistry

Future

- Assimilation system

  cloud resolving, 1 km^2, 100s of vertical levels

- Climate models

  ocean-land-biology-atmosphere-ice Earth system models
  10 x 10 km^2, 100s of vertical levels
  size, composition resolved cloud-aerosol μ-physics

Aerosol Direct Effect

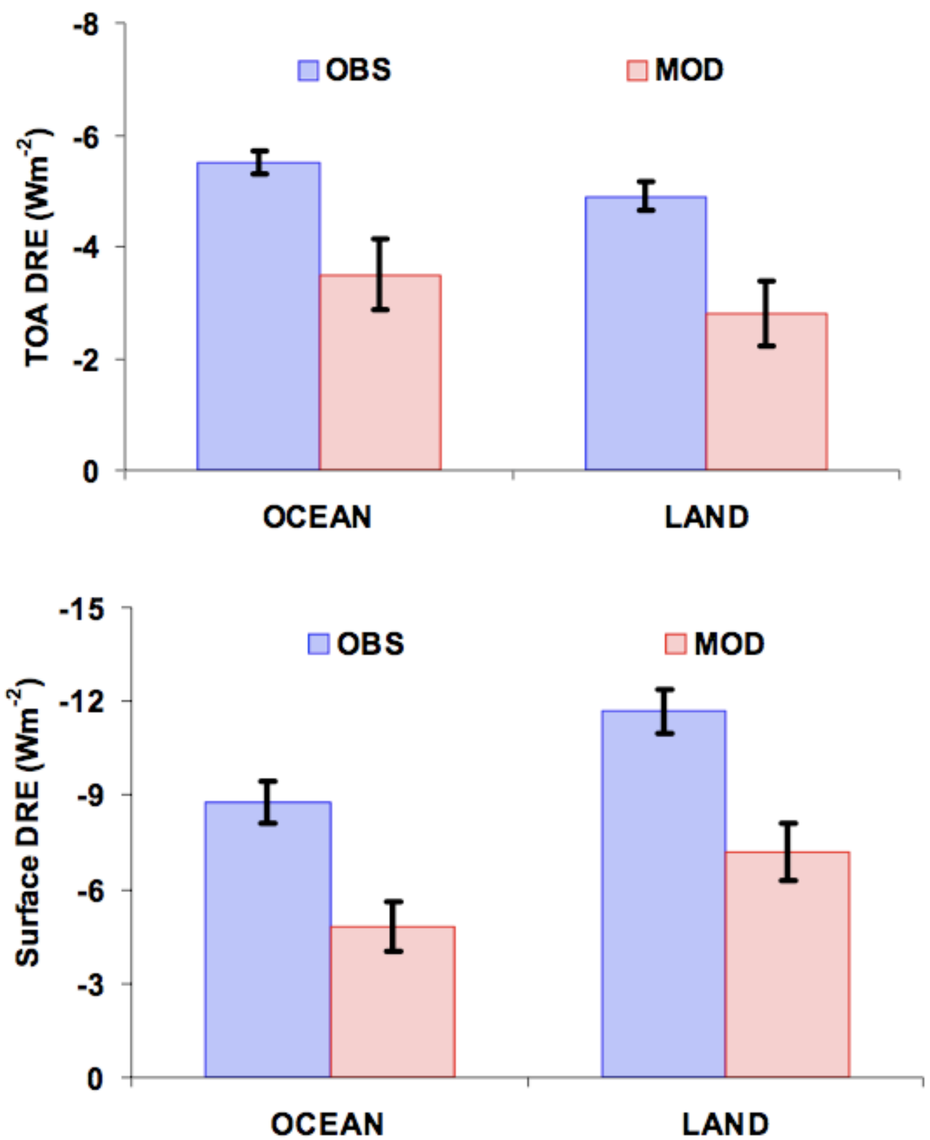


Fig. 11. Summary of observation- and model-based (denoted as OBS and MOD, respectively) estimates of clear-sky, annual average DRE at the TOA (top) and at the surface (bottom). The box and vertical bar represent median and standard error, respectively.

Yu et al. 2006, A review of measurement-based assessments of the aerosol direct radiative effect and forcing, *Atmos. Chem. & Phys.*, 6, 613-666.

Clear-Sky DRE

- models underestimate observation-based magnitude at TOA & SFC
- magnitude is relatively less well constrained over land
- outstanding issues over land include surface characterization
- also require better characterization of ϖ_0

Cloudy-Sky DRE

- require vertical structure
- diurnal variability

Anthropogenic Forcing

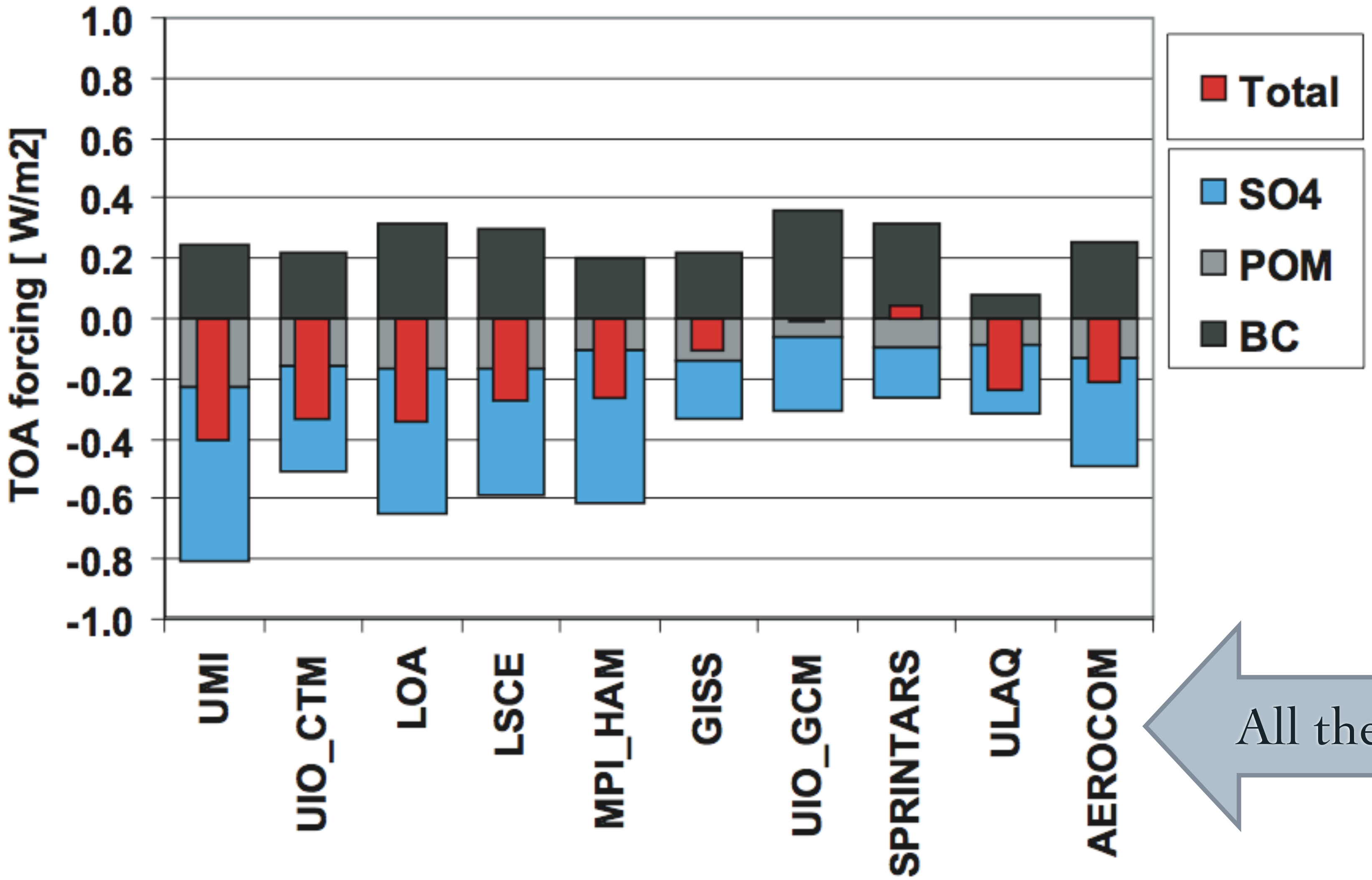


Fig. 2. Direct aerosol forcing for the three major anthropogenic aerosol components sulphate, black carbon and particulate organic matter in the AeroCom models. Shown on top in red is also the total direct aerosol forcing as diagnosed from a full aerosol run.

Model Δ

burdens (M_{SO4} = 0.6 - 1.8 Tg)
lifetimes (τ_{SO4} = 2.3 - 5.1 days)
optics (β_{ext} = 4.5 - 12.3 m^2 g^{-1})

Also notes: surface reflectance, asymmetry parameter

All these models have same emissions

Schulz et al. 2006, Radiative forcing by aerosols as derived from the AeroCom present-day and pre-industrial simulations, *Atmos. Chem. & Phys.*, 6, 5,225 - 5,246.

Diversity in Models

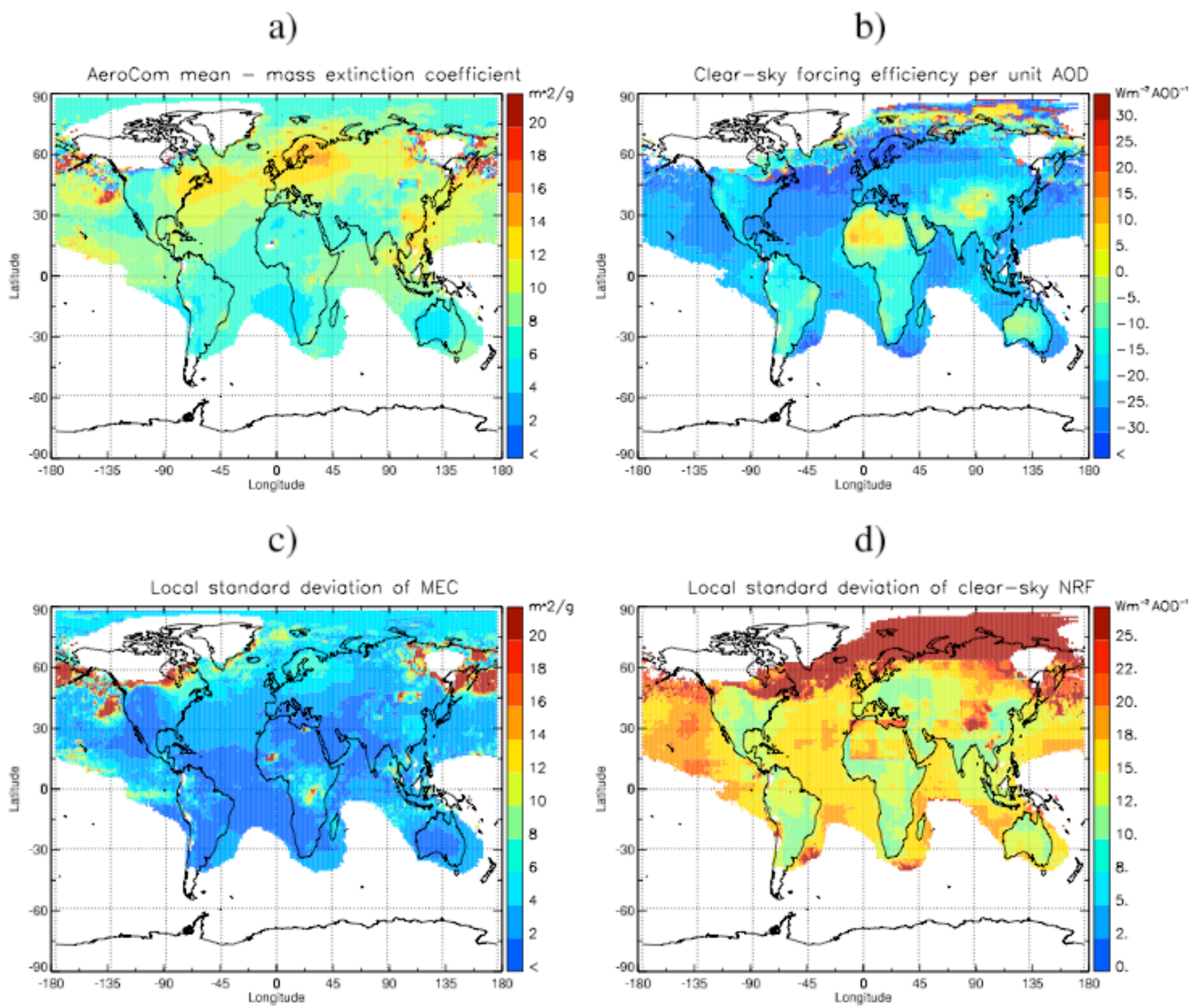
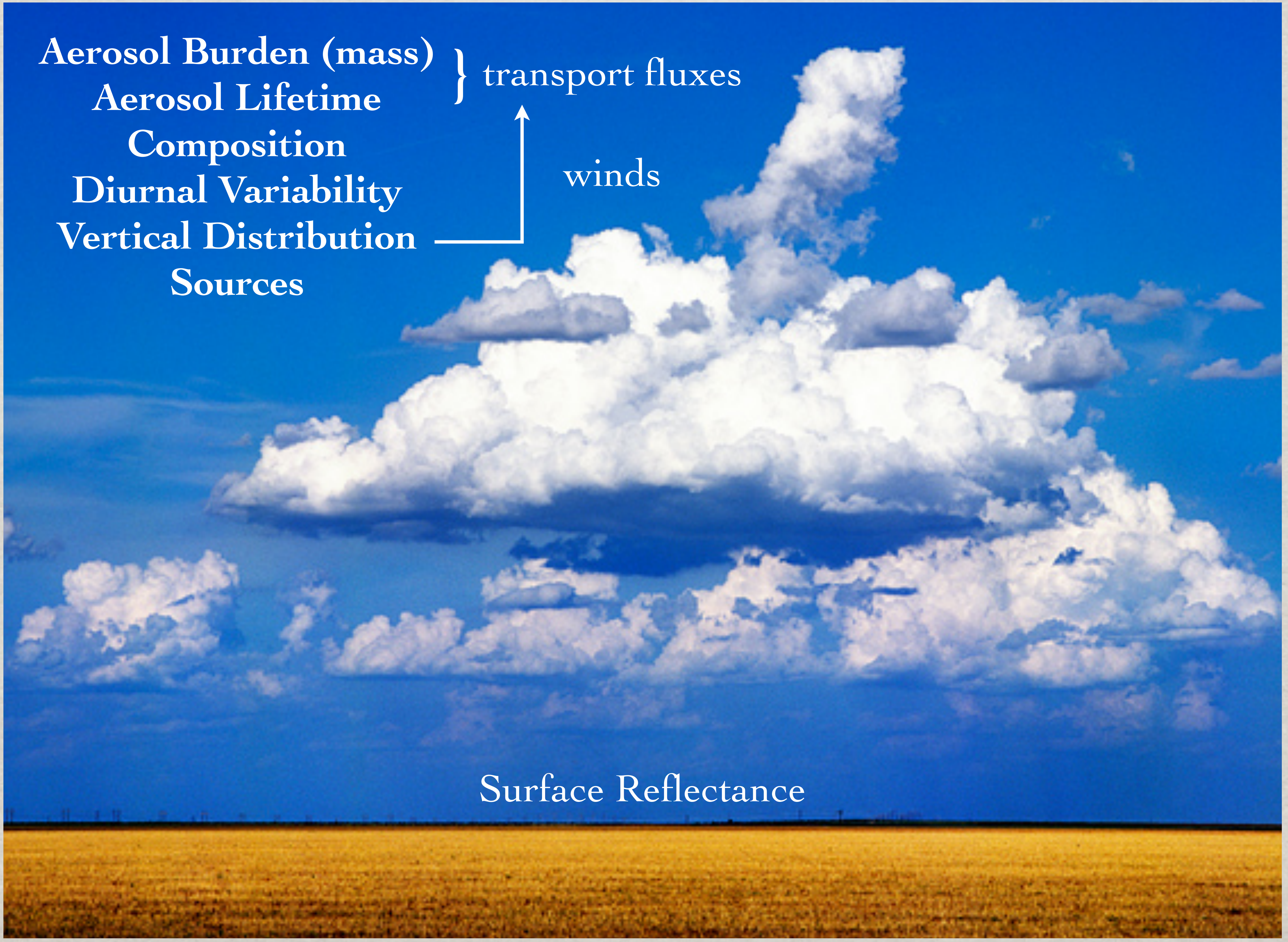


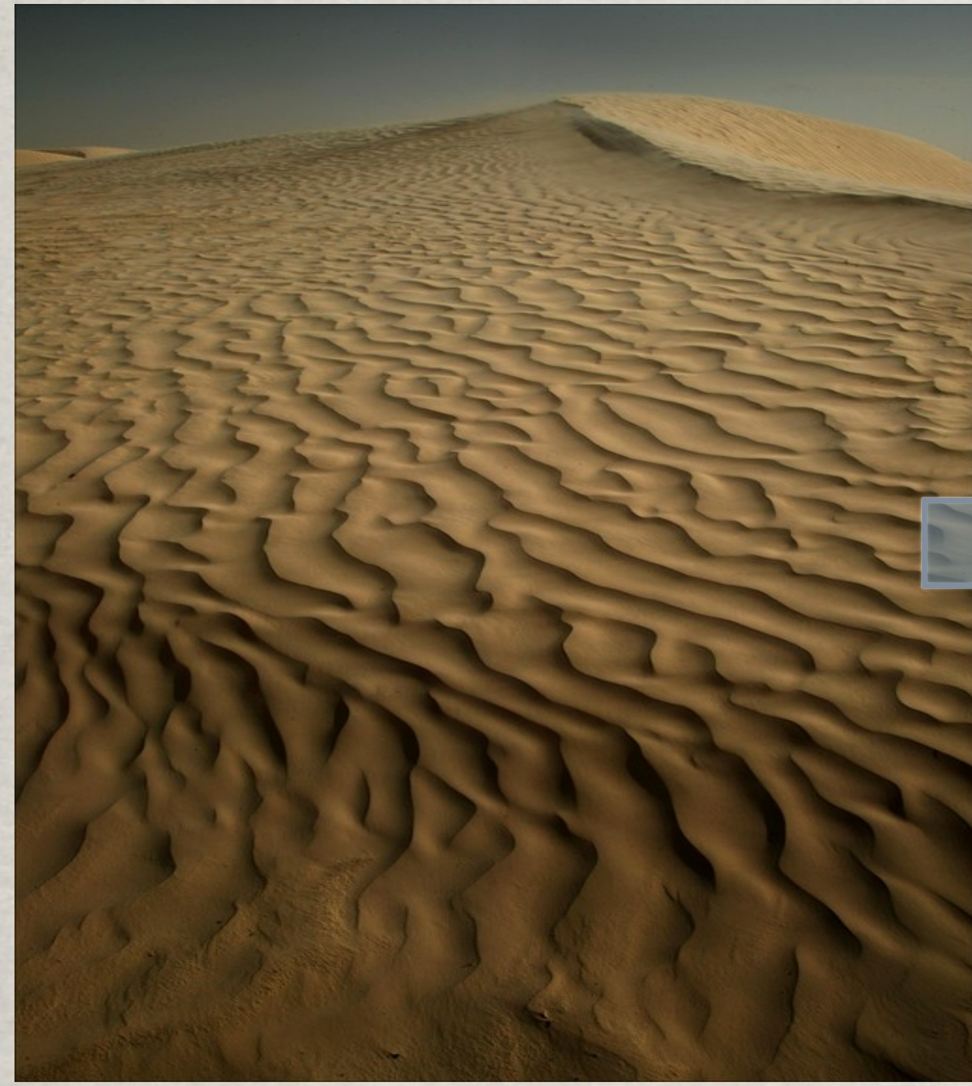
Fig. 10. Mean annual fields derived from the regridded AeroCom model simulations of **(a)** anthropogenic aerosol mass extinction coefficient, based on dry mass; **(b)** clear-sky radiative forcing efficiency per unit optical depth **(c) and (d)** local standard deviation from 8 models excluding UIO GCM for clear sky forcing efficienct. Mean and standard deviation were only computed where the anthropogenic aerosol optical depth exceeded 0.01.

Schulz et al. 2006, Radiative forcing by aerosols as derived from the AeroCom present-day and pre-industrial simulations, *Atmos. Chem. & Phys.*, 6, 5,225 - 5,246.

Requirements



Aerosol Burden & Lifetime



- 240 +/- 80 Tg of dust are transported annually from Africa to the Atlantic Ocean
- 140 +/- 40 Tg are deposited in the Atlantic Ocean
- 50 Tg fertilize the Amazon Basin
- 50 Tg reach the Caribbean
- 20 Tg return to Africa and Europe

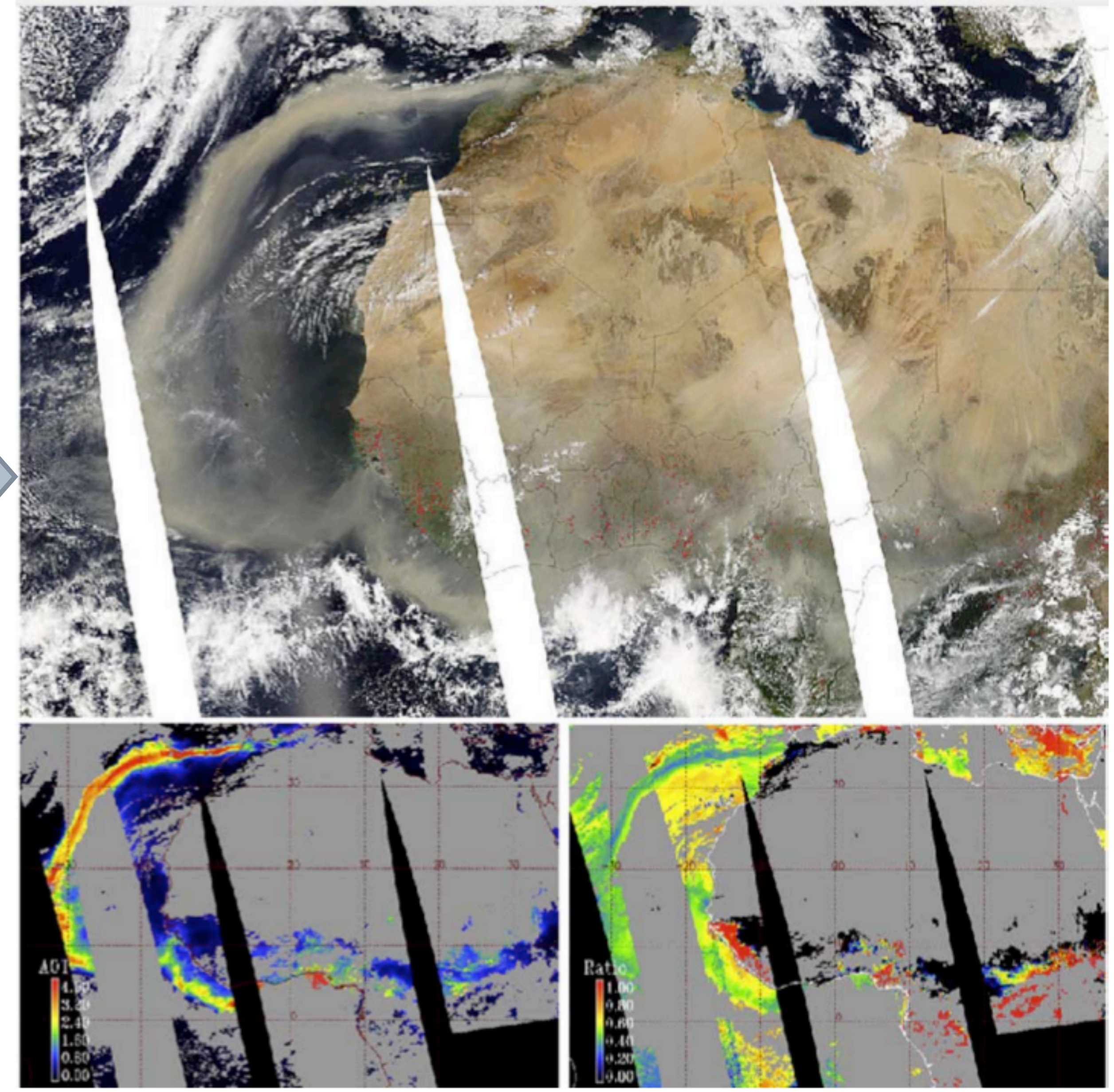
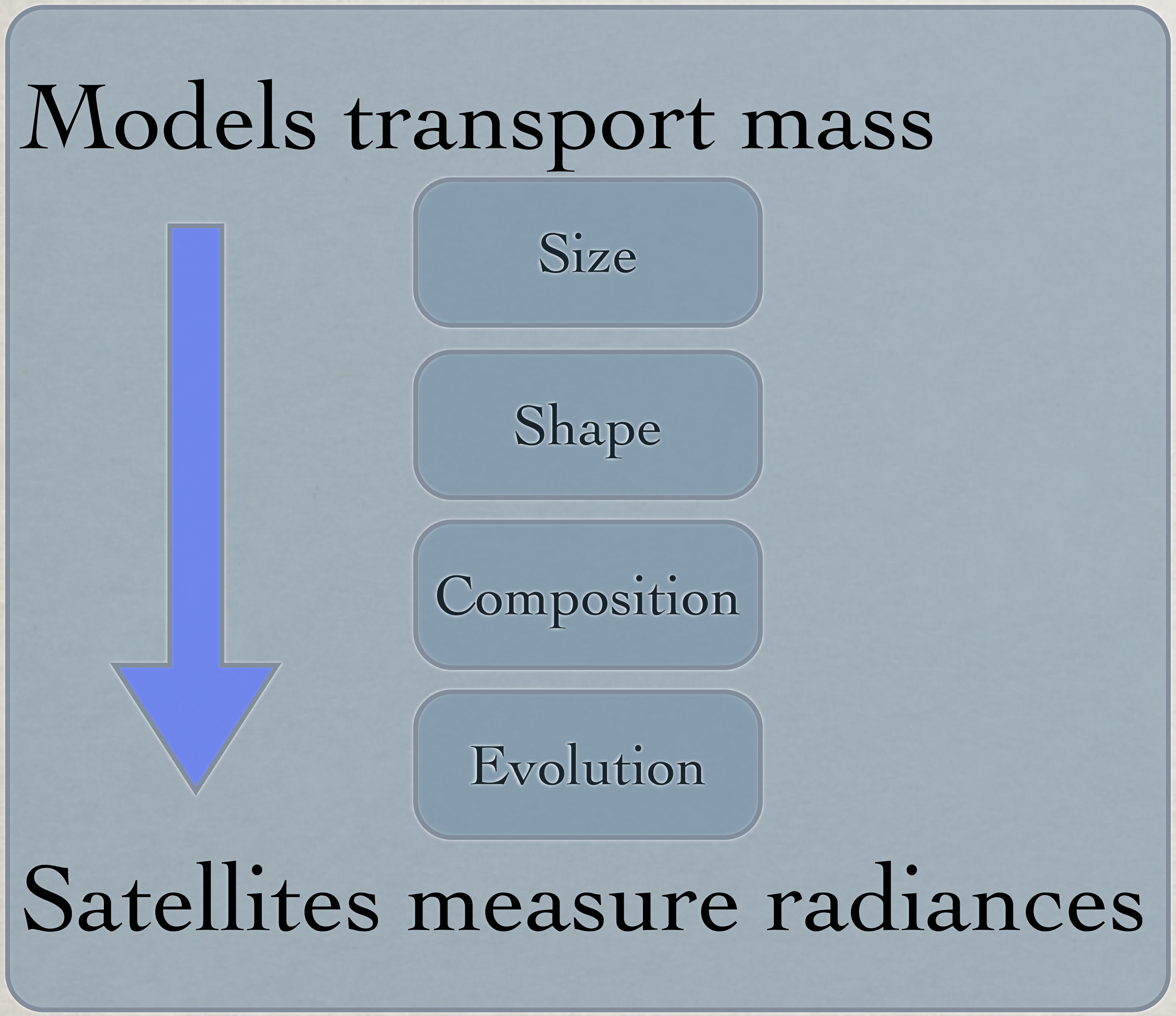


Figure 2. (top) MODIS color composite of dust storm (sand color) emerging to the Atlantic Ocean south of the Sahara and circulating in the Atlantic ocean back to northern Africa (taken from http://rapidfire.sci.gsfc.nasa.gov/gallery). Note that fires (red dots) in the south emit smoke into the dusty atmosphere. The image was taken from the Aqua satellite on 6 March 2004. The two lower panels show (left) analysis of the optical thickness of the dust, smoke, and background aerosol. The gray areas are regions where land or ocean glint are too bright to be used to derive the aerosol properties. (right) The fraction of the optical thickness due to fine (less than 1 micron diameter) aerosol particles. Blue-green colors, fraction of 0.4–0.5 represents dust; orange-red colors, fraction of 0.7–1.0 represents mixed in smoke.

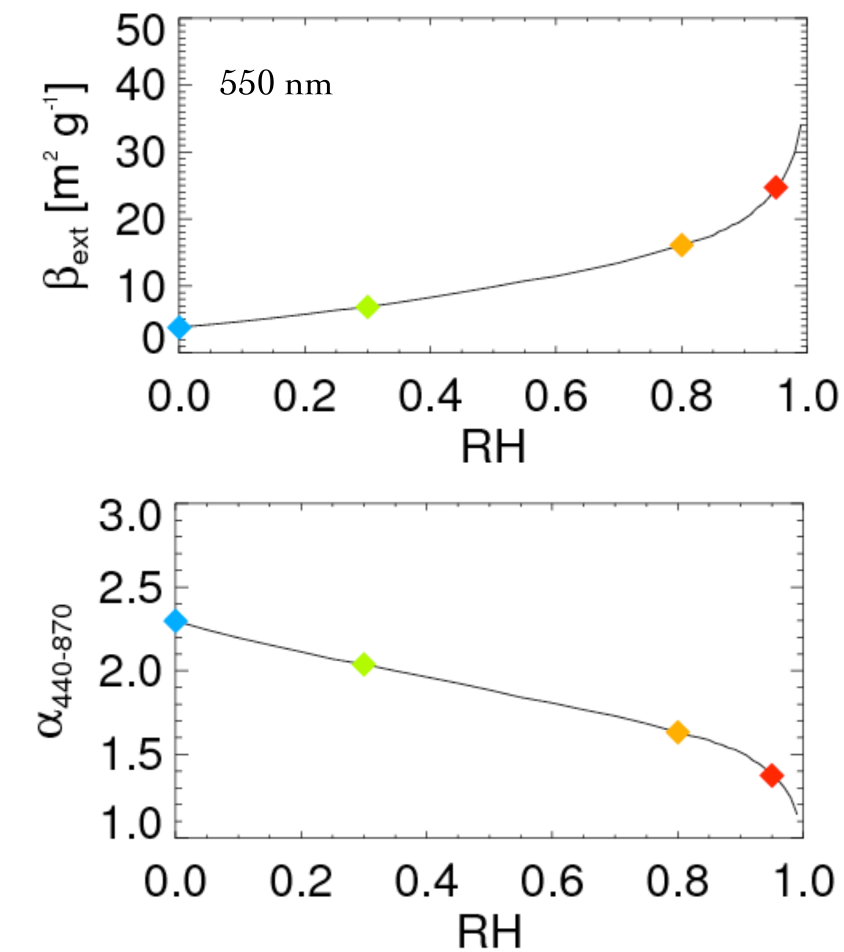
Kaufman et al. 2005, Dust transport and deposition observed from the Terra-Moderate Resolution Imaging Spectroradiometer (MODIS) spacecraft over the Atlantic ocean, *J. Geophys. Res.*, 110 (D10), doi: 10.1029/2003JD004436.

Composition



Measurement based
sulfate properties assume:

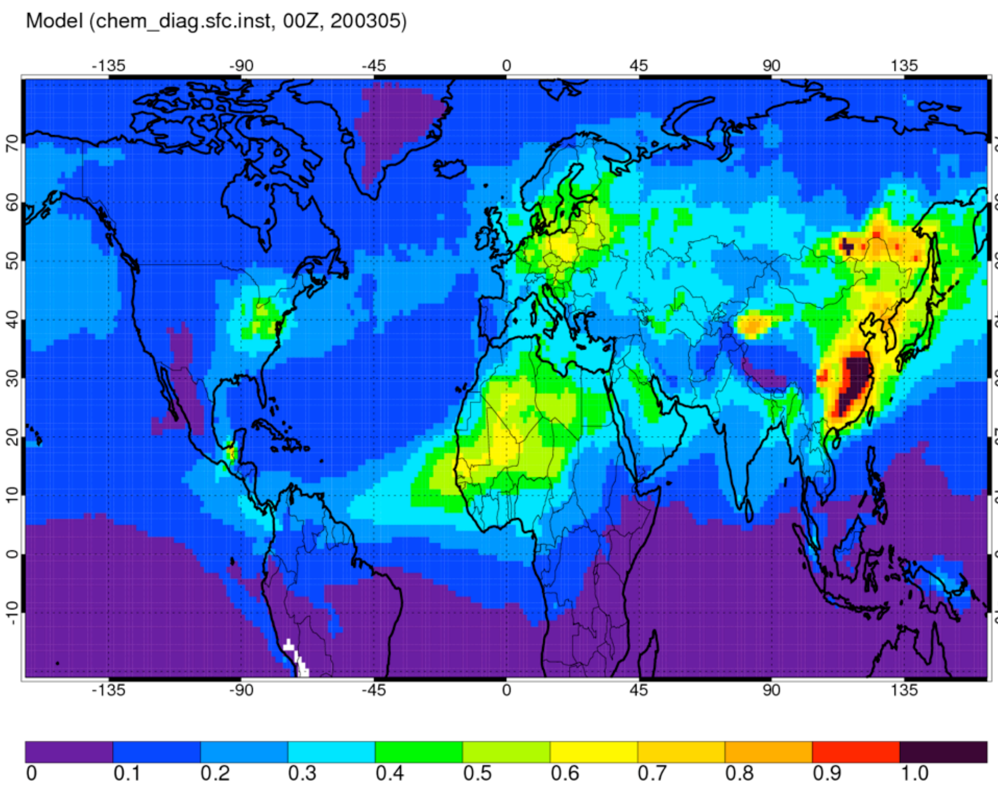
lognormal size distribution
spherical
"growth factor"
refractive index



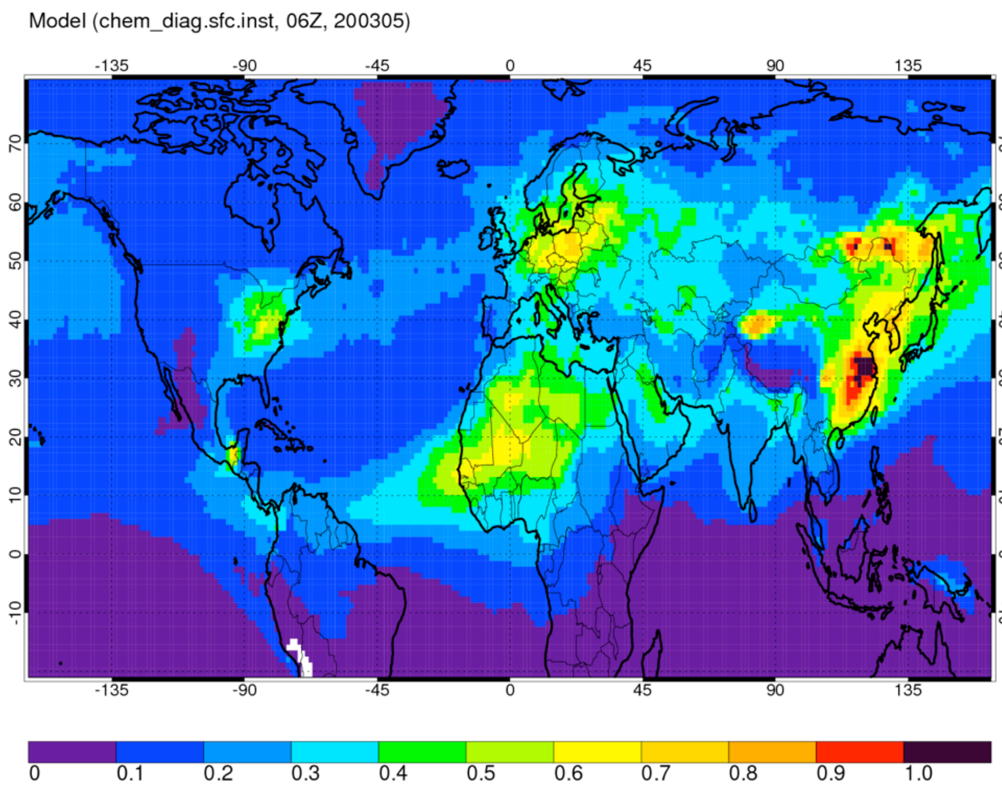
Based on Köpke et al. 1997, Global aerosol data set, Tech. Rep. 243, Max Planck Institute.

Diurnal Variability

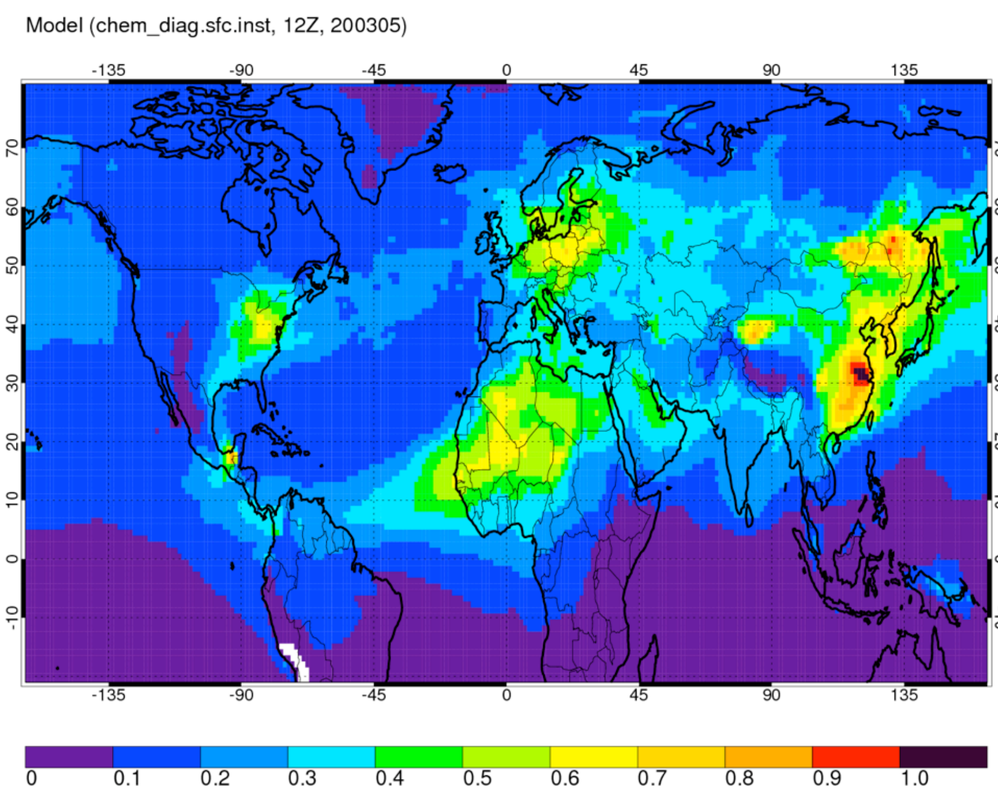
0Z



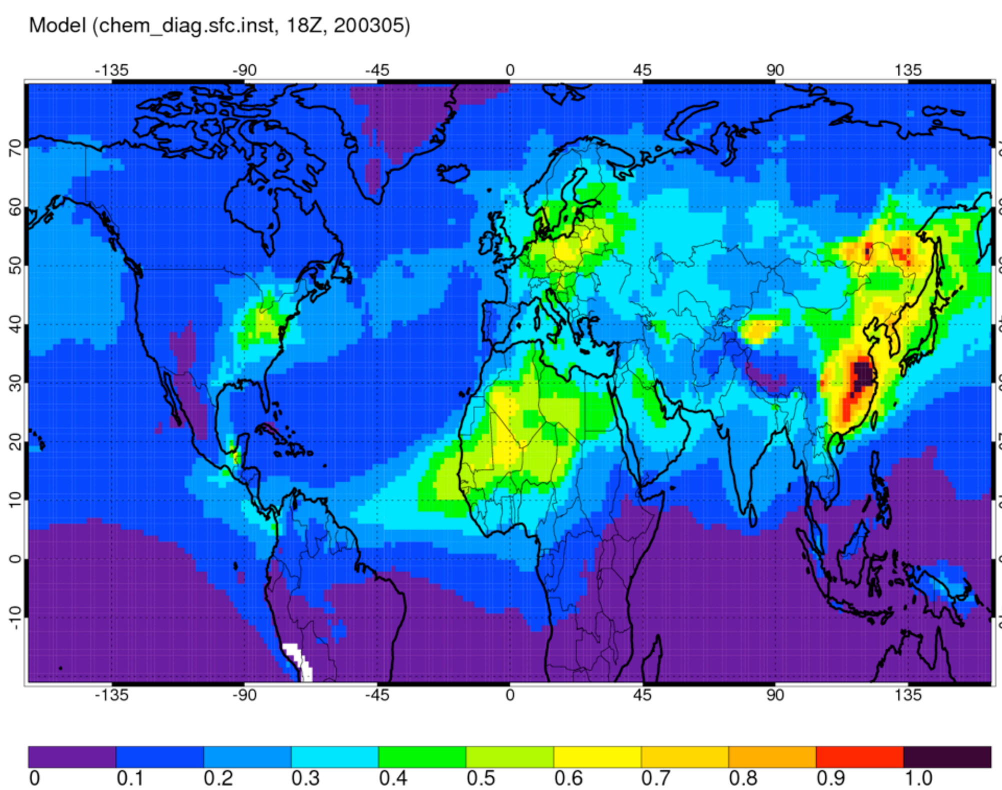
6Z



12Z

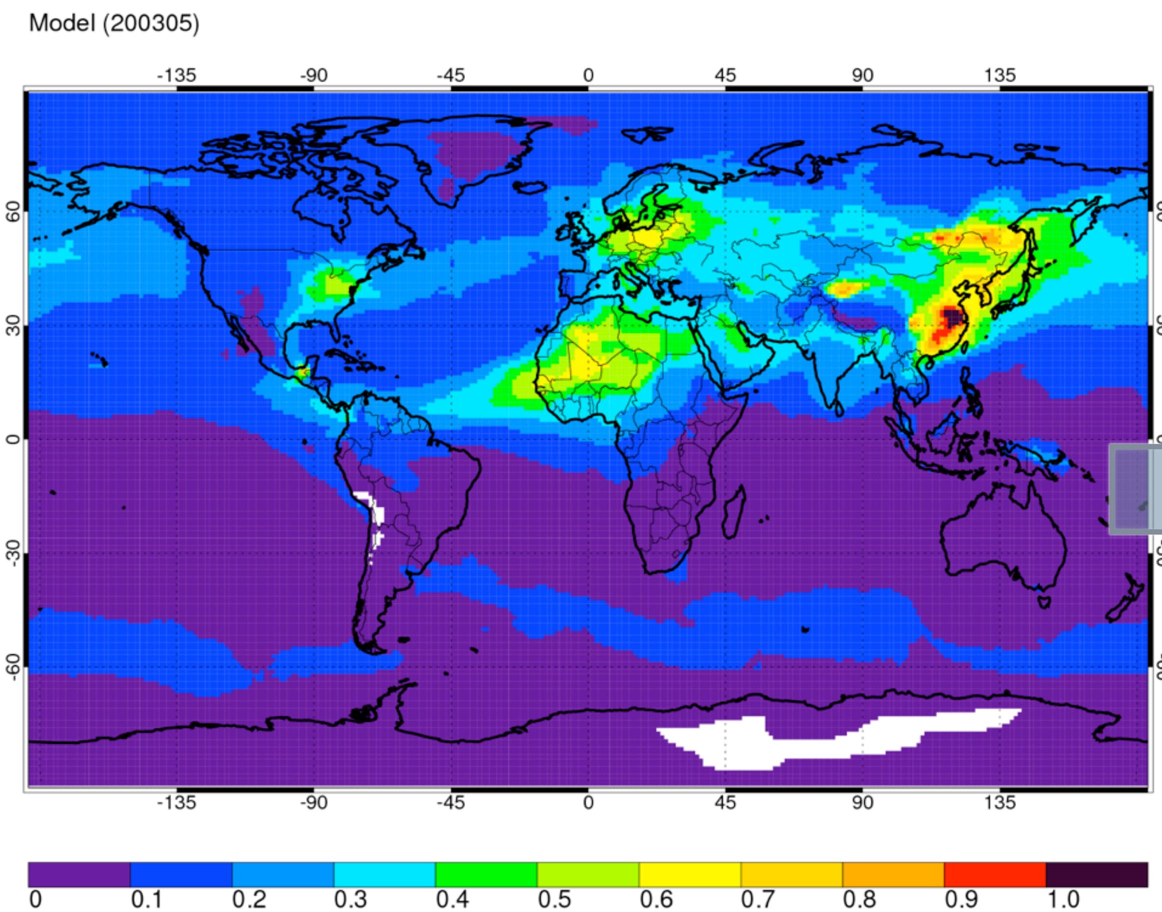


18Z

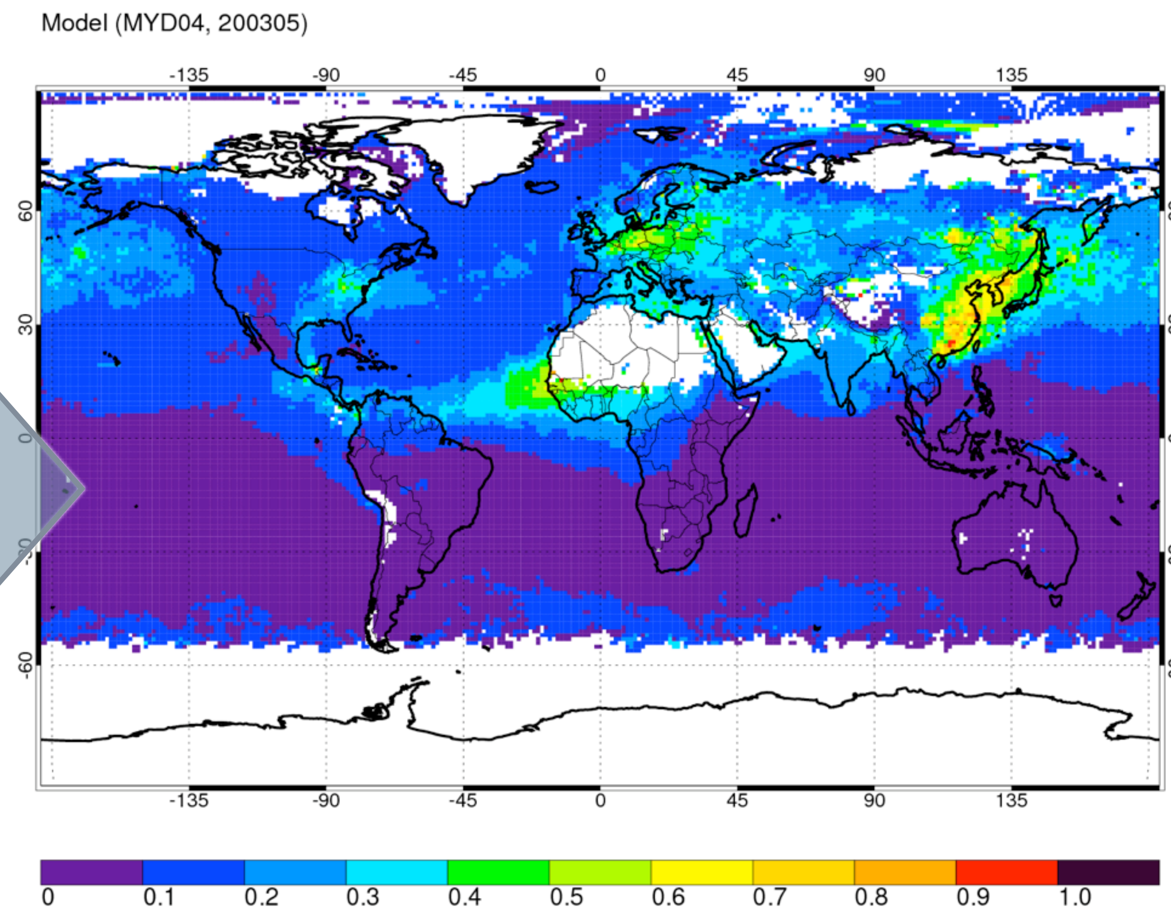


Sampling Biases

Model

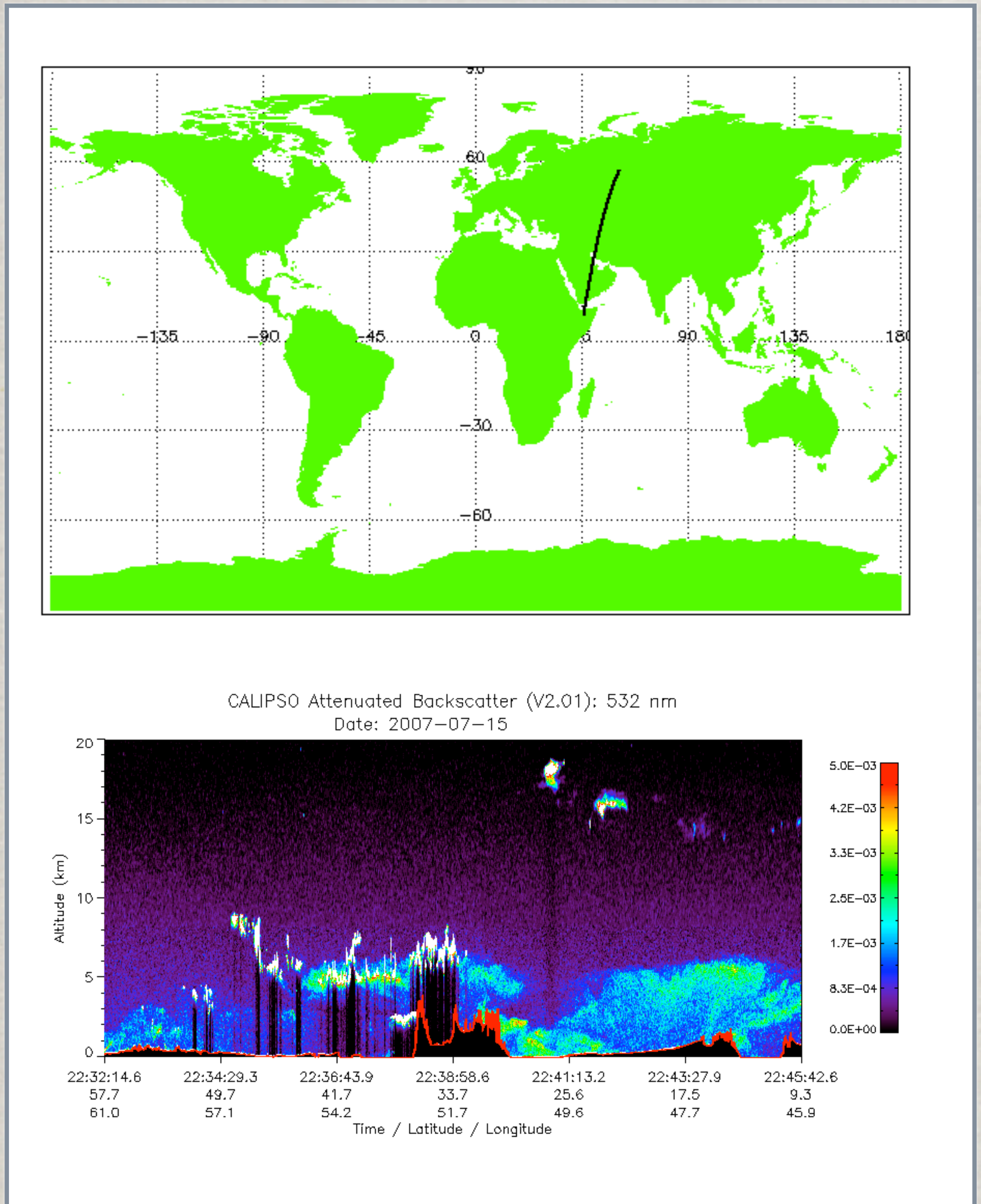


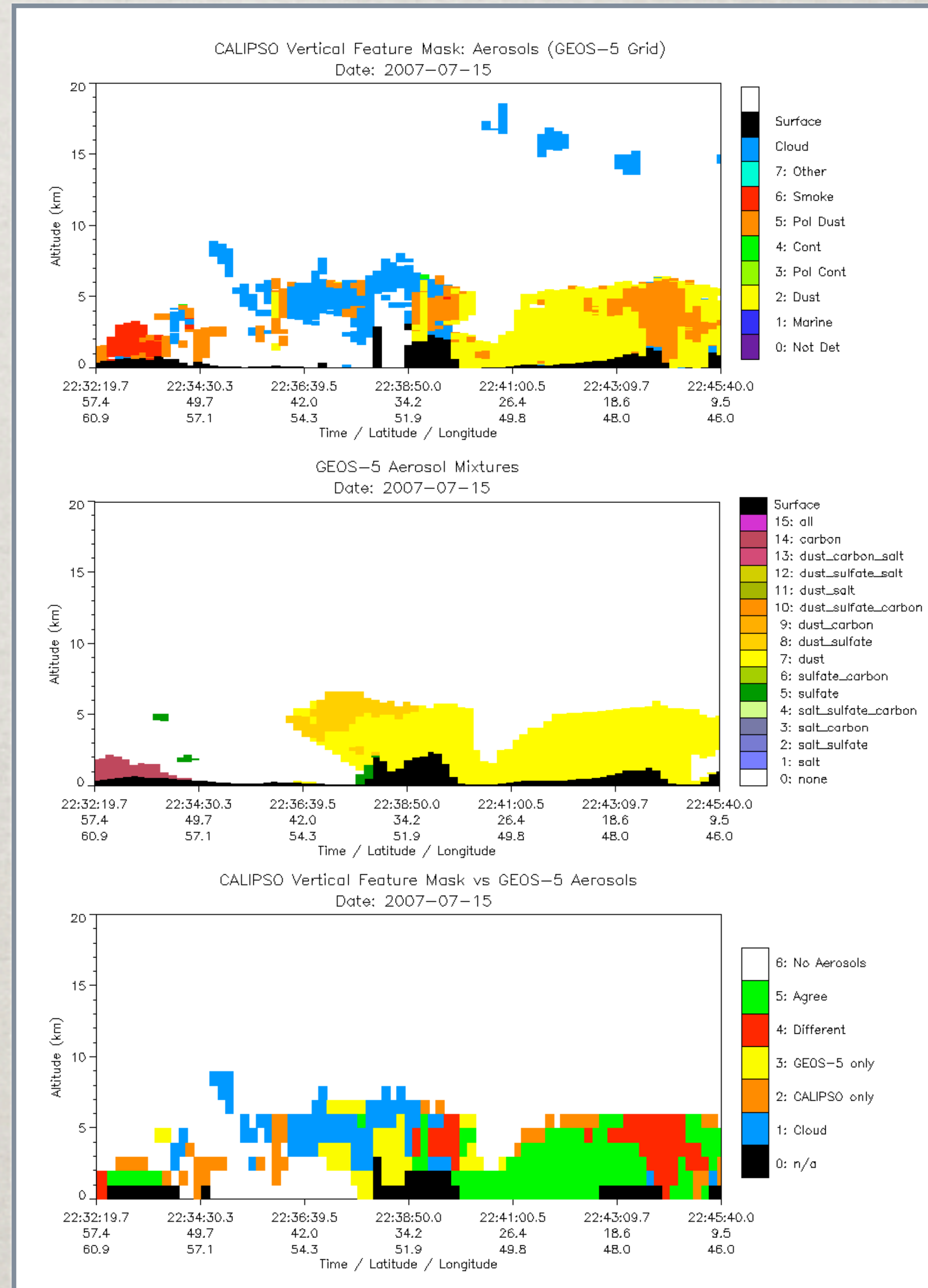
Model QA & weighted



Here the model monthly mean is shown (left) as is the monthly mean of the model sampled and weighted like the L2 MODIS Aqua retrievals (right)

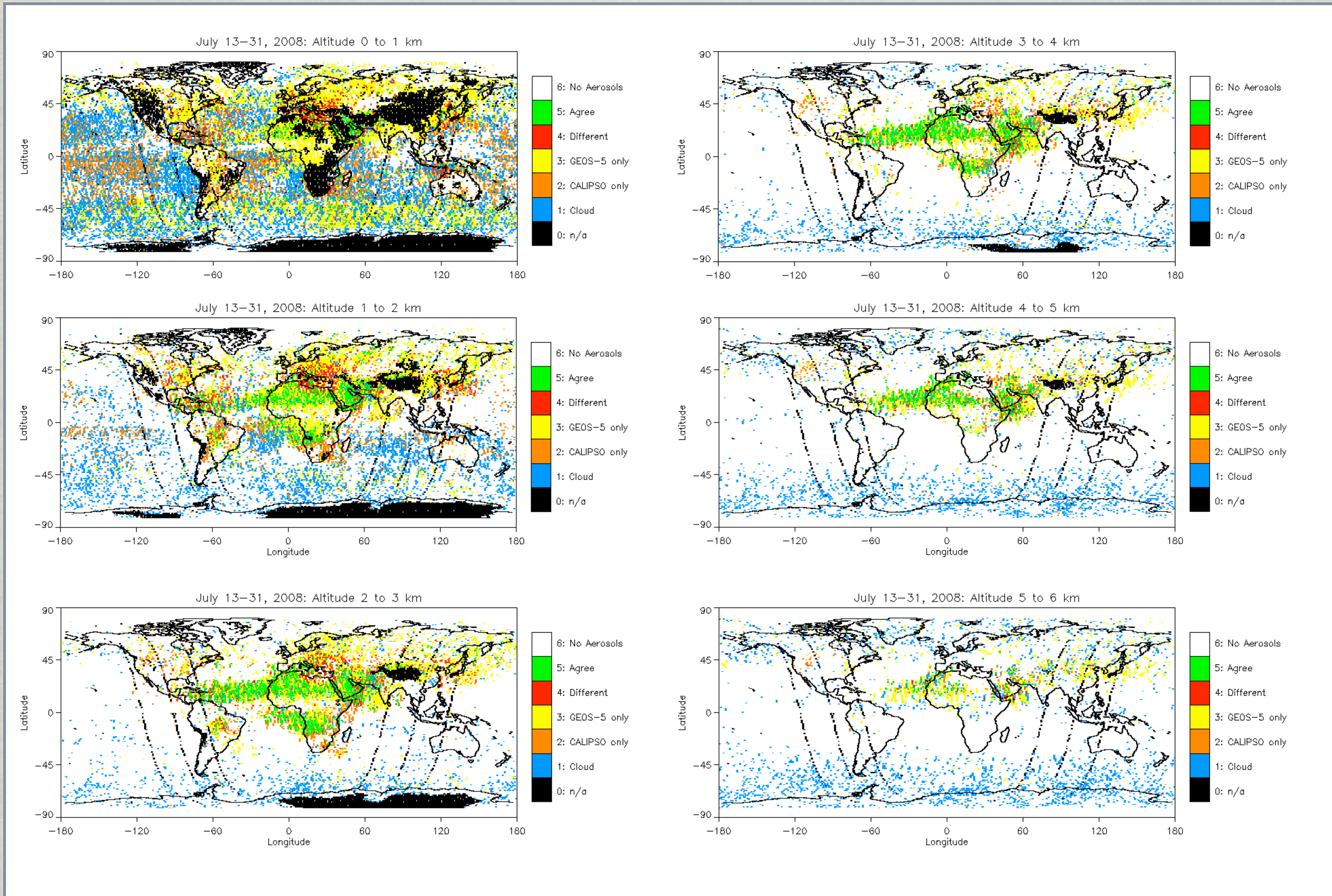
Vertical Distribution of Composition





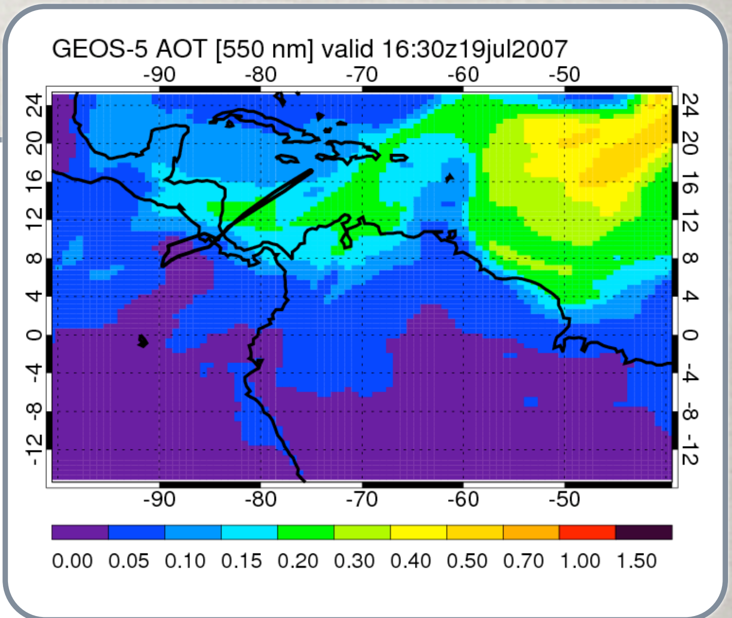
Welton et al. 2008, Comparisons of aerosol properties derived from GEOS-5 and the CALIPSO Level 2 feature mask, *Spring AGU*, Ft. Lauderdale, FL.

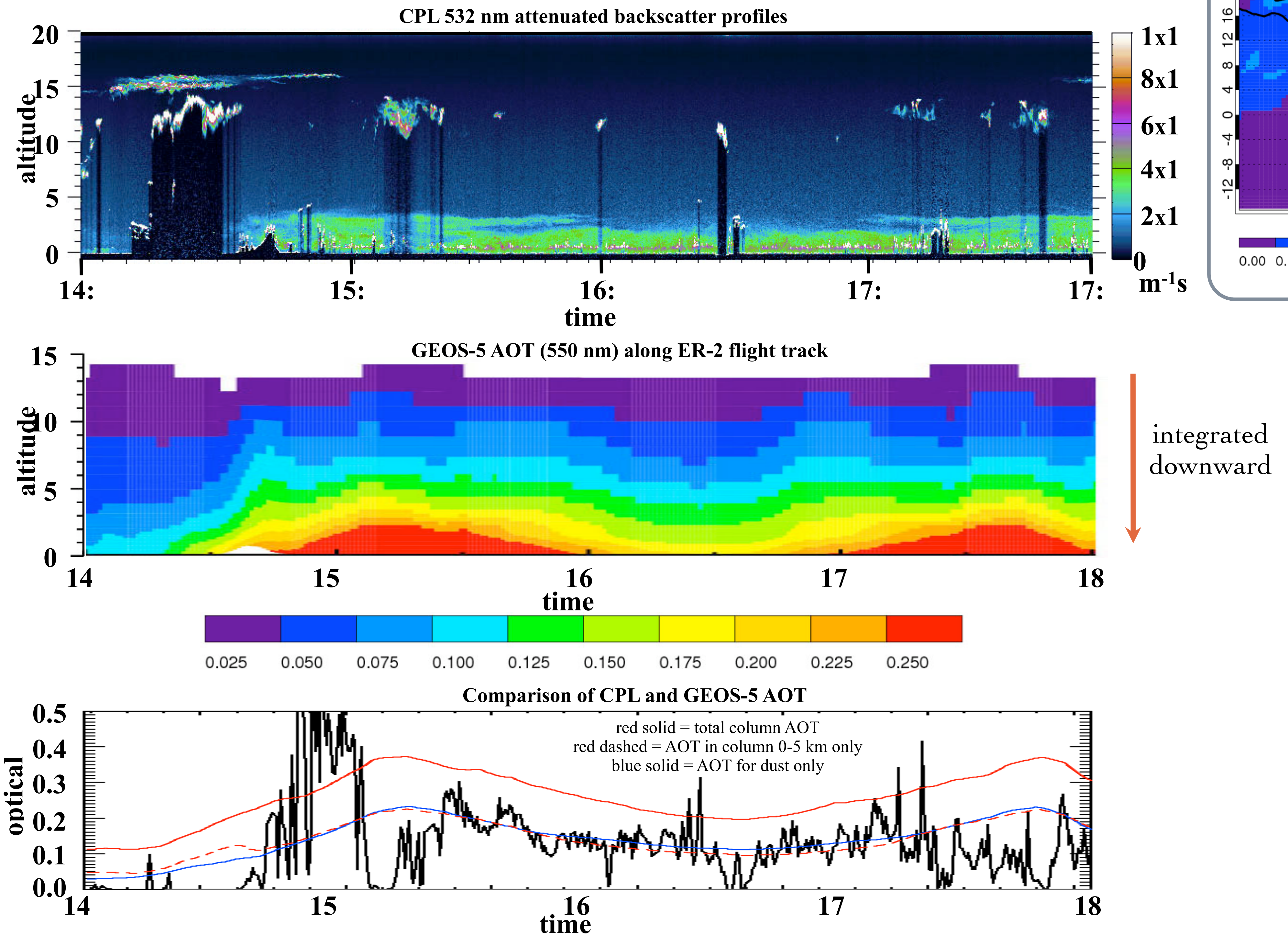
Global Aerosol Composition



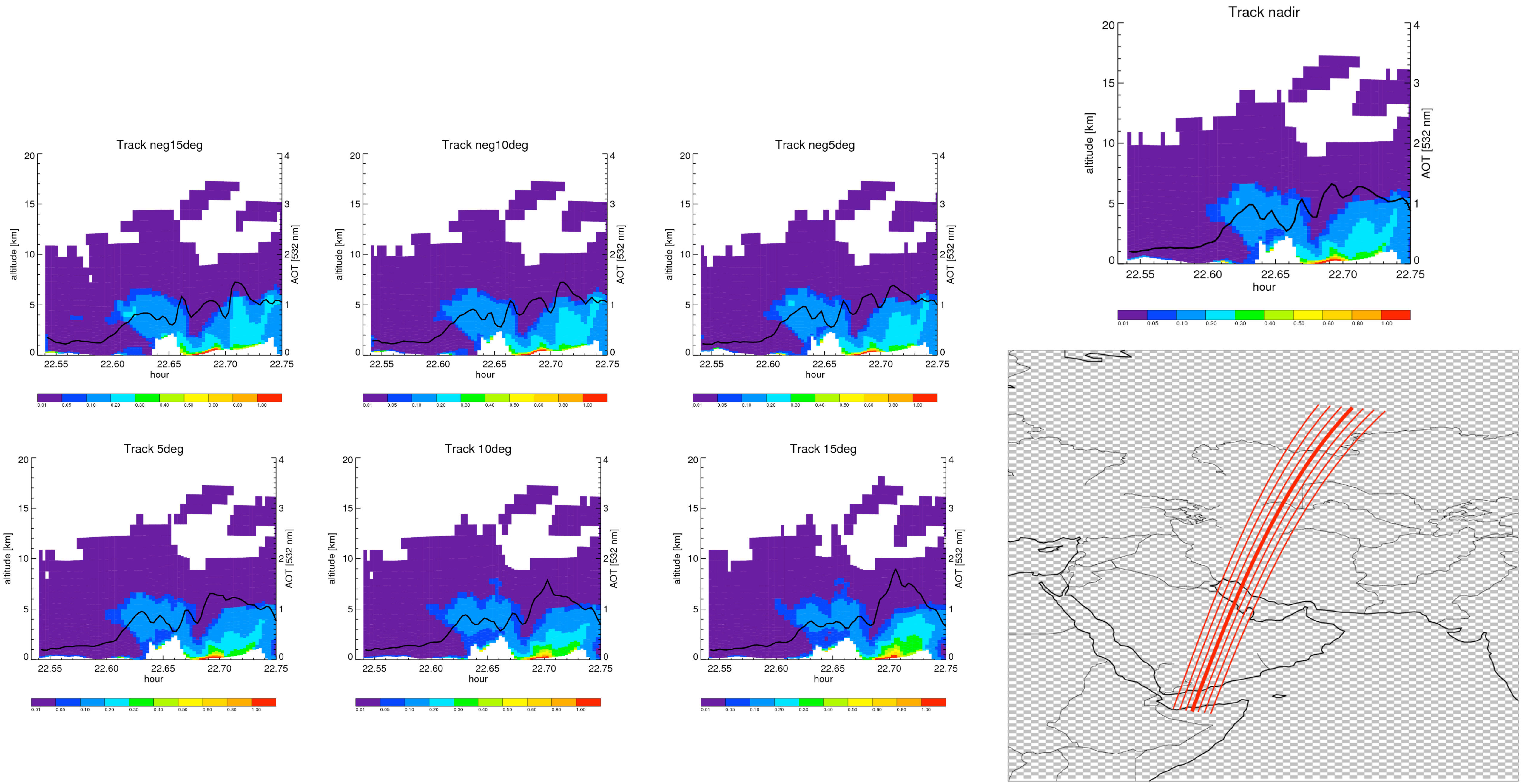
Welton et al. 2008, Comparisons of aerosol properties derived from GEOS-5 and the CALIPSO Level 2 feature mask, *Spring AGU*, Ft. Lauderdale, FL.

Source to Sink Transport





Multi-Beam Lidar



Conclusions